SPECIAL REPORT

Characterization of Decision Making Behaviors Associated with Human Systems Integration (HSI) Design Tradeoffs: Subject Matter Expert Interviews

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14. ABSTRACT
The objective of this research was to characterize the naturalistic decision making process used in Naval Aviation acquisition to assess cost, schedule and performance tradeoffs within and between Human Systems Integration (HSI) domains. Audio taped critical decision method interviews were conducted with volunteer subject matter experts (SMEs) who have performed HSI tradeoff analyses. A content analysis was performed on the transcribed data to characterize the primary macrocognition functions used in HSI tradeoff decisions. Decision requirements tables based on the interview transcripts were also created and verified through a second round of SME interviews. Finally, a list of knowledge, experience and capabilities considered by the SMEs to be required for successful HSI tradeoff decisions was generated. Using the results of this research, knowledge, skills and abilities (KSAs) specific to Naval Aviation acquisitions can be identified, which can support the future development of new processes and tools for training and decision making for HSI professionals within the Naval Aviation Enterprise (NAE).

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EXECUTIVE SUMMARY

Human Systems Integration (HSI) is typically defined by seven domains: manpower, personnel, training, human factors engineering, habitability, personnel survivability, and safety and occupational health. As a part of Department of Defense acquisition processes, HSI ensures that operator, maintainer and sustainer considerations are incorporated into military system designs. Depending on factors such as cost, schedule or desired system performance, it may be necessary to compromise on design features that can impact human performance, which results in tradeoffs within and between HSI domains.

The objective of this research was to characterize the naturalistic decision making process used by HSI practitioners to conduct domain tradeoffs for Naval Aviation acquisitions. This report describes the first phase of a proposed two phase study on HSI Tradeoff Decision Making. Five Critical Decision Method (CDM) interviews were conducted with Subject Matter Experts (SMEs) to identify (a) the primary activities conducted during HSI tradeoffs, (b) the types of factors that affect tradeoff decision making processes, and (c) the types of knowledge and experience needed to conduct tradeoff analyses. The interview data were analyzed using content analysis methods with an inter-rater reliability coding study; the data were also used to create decision requirements tables, which were validated through a second round of interviews with three SMEs.

The five case studies reported in the CDM interviews related to Acquisition Category (ACAT) I programs: two were for aircraft platforms, and three concerned subsystems and the processes required to operate or maintain those subsystems. Two case studies focused on manpower/workload, and the relevant HSI domains were manpower and HFE. Three case studies involved hardware/software (HW/SW) design changes; the relevant HSI domains were HFE, safety & occupational health, and training.

The data from the transcripts describe four general HSI tradeoff tasks: (1) evaluating a current or proposed design for human performance impact, (2) evaluating the implications of a discovered human performance impact on HW/SW design, performance, cost and schedule, (3) evaluating any potential cost, schedule and performance impacts on other technical disciplines, such as systems engineering, test and evaluation, and logistics (supportability) impact, and (4) evaluating the cost and schedule impacts on the acquisition program.

The decision requirements tables further elaborate on these HSI Tradeoff tasks. Seven decision activities were identified, with descriptions of (a) the cues that trigger each activity, (b) the factors that influence each activity, (c) the typical judgments made in the course of each activity, (d) the typical challenges faced in the course of each activity, (e) the strategies used to deal with the challenges.

The content analysis identified four primary cognitive activities associated with HSI tradeoff decision making: (1) sensemaking and situation assessment, (2) planning/adapting/ replanning, (3) uncertainty and risk management, and (4) using opportunities and leverage points. HSI practitioners are performing technical, process, risk and impact evaluations during tradeoff decisions. They are determining when and how to leverage previous work. They are planning and replanning processes for analysis, testing and implementation. They take the time to evaluate current circumstances against previously experienced analogous situations. They also interface with IPT members, stakeholders in other organizations, and individuals they worked with in the past to gather and process information and data.

Particularly for the HW/SW cases, considerable effort is made to put together a cost, schedule and performance argument to present to program management. Successfully generating this argument requires additional time and resources to gather and evaluate information on contractor work plans, available funding, cost estimates (expenditures and savings) and quantitative and qualitative HW/SW and personnel performance impacts. This further supports the need for additional research and development efforts on HSI decision support tools. Further research is also needed to identify specific HSI tradeoff KSAs, and determine which KSAs may require additional workforce training.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Department of Defense (DoD) Instruction 5000.02, Operation of the Defense Acquisition System, Enclosure 8 (2008) requires program managers to develop a Human Systems Integration (HSI) plan in order to "…optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system" (p 60). HSI addresses seven domains in support of human centered systems design: manpower, personnel, training, Human Factors Engineering (HFE), habitability, personnel survivability, and safety & occupational health.

Depending on the technical scope of the system to be designed, there is typically at least one HSI representative, or a representative from any of the seven HSI domains, serving on an acquisition program's Integrated Product Team (IPT). It is the responsibility of the designated HSI practitioner(s) to coordinate with other IPT members to ensure that over the system's lifecycle: (a) there is adequate manpower/manning, (b) the designated personnel will have the right skill sets and will be adequately trained, and (c) the system's hardware, software and processes are designed for safe and efficient use.

1.1 What is an HSI tradeoff?

Malone, Pharmer, Lockett-Reynolds, & Duma (2008) describe "tradeoffs that must be conducted among the HSI domains to achieve the most effective and affordable integration of the human element with system hardware, software, firmware, courseware, procedures, organizations, environments, and information" (p 1954). Typically, the system design features under consideration will dictate which HSI domains are relevant to a given tradeoff analysis. For example, Chapanis (1996) describes the following tradeoff scenario, which illustrates the human impacts that need to be considered in addition to hardware and software performance:

> "…suppose Function A can be performed faster on Computer System X, but Function B can be performed faster on Computer System Y…How do you strike a balance between the savings in time versus the cost of errors? Does increased operator comfort increase productivity and, if it does, how can that be translated into dollar savings? Since more highly selected personnel require less training, is it better to spend more money on selection or on training" (p 283).

From a technical standpoint, the level of coordination, data collection and data analysis required to accomplish these tasks will depend on the system's requirements and level of maturity (e.g. technology readiness levels). From a programmatic standpoint, tradeoffs will also be impacted by the acquisition program's budget and schedule. However, during the course of an acquisition program, any of these technical and programmatic factors may change, resulting in a need to reevaluate the cost, schedule or performance of the overall system and/or its components. From an HSI standpoint, this can result in tradeoffs within and between the HSI domains that impact not only human performance, but also that of operational, maintenance and support procedures.

1.2 Research in HSI Tradeoffs

Recent research in HSI tradeoffs from both the Naval Postgraduate School and the Massachusetts Institute of Technology have centered on decision support methods and tools. Simpson (2006) proposed a tool with three interfaces (an HSI Resource Search interface, a parameter interaction editor, and an HSI Trade Space Tool), which used levels of manpower, personnel, training and human engineering as inputs, and risk, cost, schedule and performance as outputs. Lazzaretti (2008) leveraged this research and the HSI Trade Space tool to evaluate operational readiness and safety as a function of manning levels using historical frigate data.

Cunio and Cummings (2009) describe a downselection decision support aid called the Systems Integration Tool for HSI Evaluation (SITHE), which was designed to help decision makers choose the best tools to evaluate HSI for a system of interest. Coley (2010) investigated the impact of the visualization techniques used in downselection tools on decision maker behaviors when using these tools.

Higgins and Mack (2006) used the responses from an alternatives analyses survey tool called ABRAHAM to identify HSI areas of high risk to equipment operators, maintainers and supporters. Desmond (2007) used the Quantified Judgment Model to compare the combat potential of two Marine Distributed Operations units, using Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, Facilities (DOTMLPF) data. Finally, Liu (2010) investigated the impact of integrating HSI into an existing systems engineering cost model, to better incorporate HSI in acquisition program planning.

1.3 HSI Tradeoff Decisions as a Naturalistic Decision Making Process

As demonstrated by previous research efforts, HSI tradeoff analyses include evaluations of the impact that different design features will have on hardware, software, and human performance. They also include making decisions or choices to select one design feature over another, considering other factors such as cost and schedule. However, conducting HSI tradeoffs is much more than a simple choice among alternatives.

As a sociotechnical system, the DoD integrated defense acquisition, technology, and logistics life cycle management system is influenced by various internal and external environmental factors such as timing and duration of each acquisition phase, IPT personnel changes, military policy, and Congressional funding. Decisions typically take place in working level IPTs, through collaboration between a variety of technical and management stakeholders. These decisions are facilitated by a high degree of deliberation in an environment influenced by technical, programmatic and organizational factors. Arguably, these characteristics of tradeoff decisions align with the eight factors that characterize decision making in a naturalistic setting (Orasanu and Connelly, 1993):

1. Ill Structured problems
2. Uncertain dynamic environments
3. Shifting, ill-defined, or competing goals
4. Action/Feedback Loops
5. Time Stress
6. High Stakes
7. Multiple Players
8. Organizational Goals and Norms

Naturalistic Decision Making (NDM) studies have been conducted using Subject Matter Experts (SMEs) in a variety of work domains, including *military operations* (Bisantz, et al, 2003; Cohen, Freeman & Thompson, 1996; Phillips, et al., 2001; Stanton, et al., 2006), *medical operations* (Fackler, et al, 2009; Patterson, Woods, Cook & Render, 2007; Wong, 2004), *system development* (Hoffman, Neville, & Fowlkes, 2009; Zannier, Chiasson, & Maurer, 2007), *information technology project management* (Taylor, 2007), and *airline safety* (Macrae, 2009). Cognitive task analysis methods have been used to study NDM in a variety of work domains. Combinations of techniques such as Critical Decision Method (CDM) interviews, questionnaires, think aloud protocols and direct observations have been used to collect data on individual and team decision making (Crandall, Klein, & Hoffman, 2006).

1.4 Research Objectives and Goals

The objective of this research was to empirically investigate the NDM processes used by HSI professionals on Naval Aviation acquisition programs to assess cost, schedule and performance tradeoffs within and between HSI domains. The goals of this research were to investigate HSI tradeoff decision making CDM and decision requirements table interviews with HSI SMEs. The original scope of this research also included a plan to conduct a computer based decision making assessment study using inputs from both novices and experts. However, due to project resource constraints, only the CDM and decision table interviews were completed. This report documents the results of these interviews.

CDM is a knowledge elicitation method specifically designed to facilitate the recollection of decision making processes used in specific non-routine or difficult incidents (Klein, Calderwood, & MacGregor, 1989). Participants are asked to recount the timeline and details of the incident through a series of probe questions that target different cognitive aspects of the decision, such as goals, mental modeling, and errors made or avoided (Hoffman, Crandall, & Shadbolt, 1998). Depending on the research focus, the probe questions are tailored to highlight specific cognitive processes of interest.

As described by Klein (1998), a decision requirements exercise enables decision makers "to identify (1) key judgments and decisions facing them, (2) why they are difficult, and (3) where they can go wrong. These decision requirements are the high drivers, the specific decision skills that they need to polish" (p. 105). The results of CDM interviews can be used facilitate the creation of these decision tables. For example, Wong (2004) generated incident summaries and a decision chart that provided the necessary information to produce a decision analysis table. Phillips, McDermott, Thordsen, McCloskey, & Klein (1998) combined findings from CDM, knowledge audit and task diagram interviews to generate initial decision requirements tables that were later validated with additional SME inputs (Phillips, et al., 2001).

This research in HSI tradeoff decision making facilitates the identification of knowledge, skills, and abilities, which is a critical step in determining (a) which tradeoff decision tasks may require additional workforce training and, (b) which tasks are candidates for automation aids, and are worth spending additional resources to develop some kind of decision support tool. Such efforts support the development of the S&T workforce, as well as enhanced HSI and acquisition process capabilities.

As described in the 2009 Naval Science and Technology (S&T) plan, the primary drivers for total ownership cost are acquisition of platforms and systems, maintenance and life-cycle, and manpower. Because HSI domain tradeoff analyses impact each of these cost drivers, it is beneficial for the Naval Aviation Enterprise (NAE)/Navy to continuously improve the HSI

methodologies used to perform such analyses throughout the acquisition lifecycle. More accurate human related cost, schedule and performance tradeoffs will not only impact the quality of manpower optimization and training effectiveness efforts, but will also increase system and platform affordability and availability.

2.0 METHOD

For the CDM and decision requirements table interviews, approval from the Institutional Review Boards at both the Naval Air Warfare Center Training Systems Division (NAWCTSD) and the Naval Air Warfare Center Aircraft Division (NAWCAD) Patuxent River was obtained.

2.1 Participants

This research required the participation of HSI SMEs with at least eight years of experience in Naval Aviation acquisition, and at least five years of experience specifically conducting aviation related HSI tradeoff analyses. Potential participants for this study were identified by AIR 4.6 management. Each individual was then recruited via email request from the study's principal investigator to voluntarily participate in this study.

Five CDM interviews were conducted over the course of three months. Three of these five individuals also participated in the decision requirements table interviews, which were conducted over a two month period. Table 1 summarizes the demographic profiles of the CDM interview participants.

Table 1: CDM Interview Participant Demographic Profiles

Educational background	Psychology (Four participants) Engineering (One participant)
Years of DoD acquisition experience	Range: 8-28 years
Years of Naval Aviation work experience	Range: 4-28 years
Years of HSI	Range: 5-27 years
Years of experience on the specific acquisition program when the decision occurred	Range: 6 months – 3 years
Years of total acquisition experience when the decision occurred?	Range: 4 – 18 years

2.2 Critical Decision Method Interviews

For this research, structured critical decision method (Hoffman, et al., 1998; O'Hare, Wiggins, Williams, & Wong, 1998; Taylor, 2007) interview questions were used. The questions were peer reviewed before subject recruitment began. The interview protocol and a list of the demographics and probe questions are provided in Appendix A.

2.2.1 Data Collection

Signed informed consent forms were obtained from all study participants. All interviews were recorded to support data transcription, and were conducted in a closed door conference room to better control ambient noise for the recording equipment. Each interview lasted approximately 1.5 – 2 hours. All interviews were unclassified.

SMEs were first asked demographic questions (e.g. educational background, years of acquisition experience, etc). Next, they were asked to provide a high level description of an HSI tradeoff that occurred within the last five years, and describe the details about that incident. Probe questions centered on factors like the timeline of events, interactions between personnel, planning activities, analogous situations, mental modeling, and the use of experience.

2.2.2 Data Analysis

In the transcription of the audio files generated from the interviews, the anonymity of each participant was protected by (1) replacing subject names with a participant number, (2) replacing specific acquisition program names with its designated Acquisition Category (ACAT) level, which categorizes a program by expenditure amount, and (3) replacing the names of other personnel mentioned with their job title or a similar descriptor.

After the audiotapes were transcribed, a content analysis for coding and emergent themes was performed (Krippendorff, 2004; Neale & Nichols, 2001; Neuendorf, 2002). All four coders who participated in the analysis were at least Defense Acquisition Workforce Improvement Act (DAWIA) Level I certified in Systems Engineering and had either a degree and/or relevant work experience in Human Factors.

All of the data in the transcripts except the responses to the "Experience" and "What-If" questions were used in the coding analysis; the "Experience" and "What-If" responses were analyzed separately. The codes used in this research were based on the macrocognition functions and processes commonly found in cognitive task analysis research, described by Crandall, et al. (2006) and Klein (1998) as "the collection of cognitive processes and functions that characterize how people think in natural settings" (p 136). These are higher level cognitive processes (e.g. managing attention by determining what tasks to focus on), as opposed to microcognitive processes (e.g. serial vs. parallel attention processing).

An inter-rater reliability study was completed in three phases. In the first phase, two transcripts were used to reduce the total number of macrocognition functions and processes to the following four codes:

- <u>Sensemaking and Situation Assessment</u>
  - Did someone perceive or evaluate information?
  - Did someone diagnose a situation?
  - Did someone anticipate how a situation might develop in the future?
- <u>Planning/ Adapting/Replanning</u>
  - Did someone create a strategy to complete specific activities within a certain timeframe?
  - Did someone modify, adjust or replace a plan that was already being implemented?
- <u>Uncertainty and risk management</u>
  - Did someone **<u>not</u>** know or **<u>not</u>** understand something which impacted or would impact how the tradeoff analysis proceeded (e.g. critical data were missing or considered unreliable, goals were unclear, problems were not clearly stated, or people were not sure what to do next)?
- <u>Using opportunities and leverage points</u>
  - Did someone turn an opportunity or a leverage point into a course of action?

Klein (1998) describes a leverage point as an occurrence that can impact the direction of a given situation: "Leverage points are just possibilities - pressure points that might lead to something useful, or might go nowhere (p116)...Leverage points provide fragmentary action sequences, kernel ideas, and procedures for formulating a solution" (p117).

The identification of these four codes as most relevant to HSI Tradeoffs was accomplished over several iterations, which were facilitated by a calculated percent agreement between coders, and subsequent consensus building discussions to further refine how best to interpret the text selections from the transcripts.

To calculate rater reliability scores, a boundary based method similar to Carletta, et al. (1997) was initially used. The calculated Kappa score using this method reflects the agreement between raters on the number of times the codes are used for each boundary. However, the resulting Kappa values were very low because the percent error was very close to the percent agreement, despite having over 30 boundaries for each of the two transcripts. This was attributed to the fact that the procedure required each coder to review every text selection four times, once for each code, and respond either "Yes" or "No" if a code applied. Fleiss' Kappa (Fleiss, 1971; Gwet, 2010) was then used, because it is a similar method of assessing agreement on the assignment of categorical ratings. However, this Kappa was also very low. Therefore, it was decided to rely primarily on only percent agreement and consensus. Percent agreement was 47% after the first coding phase.

The second coding phase was performed to further validate the use of four codes, using a representative data set that included 71 text selections from across all five transcripts. The same "Yes/No" procedure was used to categorize text selections. After the second phase, percent agreement for each code was over 60%.

The final phase was performed using the four codes on 229 text selections from all five transcripts. This phase used the same "Yes/No" procedure. Fifty text selections were not assigned to any of the four codes; the coders determined that they contained repeated and extraneous information, such as commentary on or embellishment of already stated facts. For the remaining 179 segments, more than one code could be assigned to each text selection if deemed applicable. After each text selection was coded, emergent themes were generated within each code; a text selection could be assigned to more than one theme. Percent agreement was not calculated in this phase; only consensus was used.

2.3 Decision Requirements Table Interviews

In parallel with the final coding, decision requirements tables were created using the contents of the same five transcripts. Three researchers worked on the sequential lists that were used to create the initial decision tables, following the method described by Wong (2004). Two researchers developed the initial decision requirements tables using the sequential lists; no coding took place, only team consensus. For each decision activity in the table, there is a list of (a) cues that trigger the activity, (b) factors that influence the activity, (c) typical judgments made in the course of the activity, (d) typical challenges faced in the course of the activity, (e) strategies used to deal with the challenges.

The same potential participants that were identified for the CDM interviews were recruited via email to participate in the decision table verification and validation interviews. Interview questions were peer reviewed before subjects were recruited for the decision table verification and validation interviews. Participants were asked to review the contents of the tables and recommend corrections and edits. SMEs were also asked to describe decision

characteristics that clearly distinguish experts from novices. The interview protocol for decision table verification and validation is provided in Appendix A.

2.3.1 Data Collection and Analysis

A pilot study with one SME was conducted to verify the contents of the tables and the appropriateness of the interview questions. Signed informed consent forms were obtained from all study participants. All interviews were recorded to support data transcription, and were conducted in a closed door conference room to better control ambient noise for the recording equipment. Each interview lasted approximately 1 – 1.5 hours. All interviews were unclassified.

At the end of data collection, the interview recordings were transcribed and reduced to update the initial decision requirements tables with the inputs from the SMEs. A summary of the identified Novice/Expert differences was also created.

3.0 RESULTS

This section describes the key findings from the summarized results of the CDM and decision table interview data.

3.1 Case Study Summaries

All five case studies related to ACAT I programs: two were for aircraft platforms, and three concerned subsystems and the processes required to operate or maintain those subsystems. Two case studies focused on manpower/workload, and the relevant HSI domains were manpower and HFE. Three case studies involved hardware/software (HW/SW) design changes; the relevant HSI domains were HFE, safety & occupational health, and training. The summarized responses to the CDM interview probe questions can be found in Appendix B.

The manpower case studies were not tradeoffs in the true sense of the word. They were more of an evaluation of the known design tradespace, to verify if the existing manpower estimate was valid for the design, and whether or not the design added workload. However, for one of these case studies, a workload impact was discovered. As a result, technical analysis for an appropriate mitigation and a cost analysis for a contract modification were performed.

The HW/SW tradeoffs were system design tradeoffs. In each case, evaluations and analyses were performed to clearly articulate the impact of a particular design feature on the operator's or maintainer's ability to interact with the system as intended, in both mission execution and emergency scenarios. Potential impacts on training were also identified in two of the case studies.

The data from the transcripts describe four general HSI tradeoff tasks: (1) evaluating a current or proposed design for human performance impact, (2) evaluating the implications of a discovered human performance impact on HW/SW design, performance, cost and schedule, (3) evaluating any potential cost, schedule and performance impacts on other technical disciplines, such as systems engineering, test and evaluation, and logistics (supportability) impact, and (4) evaluating the cost and schedule impacts on the acquisition program. These four activities may seem sequential, but they are actually concurrent as depicted in Figure 1. Not only can different IPT members work on each task in parallel, but conditional or preliminary analyses with documented assumptions can be performed in each area, then revised as additional information becomes available.

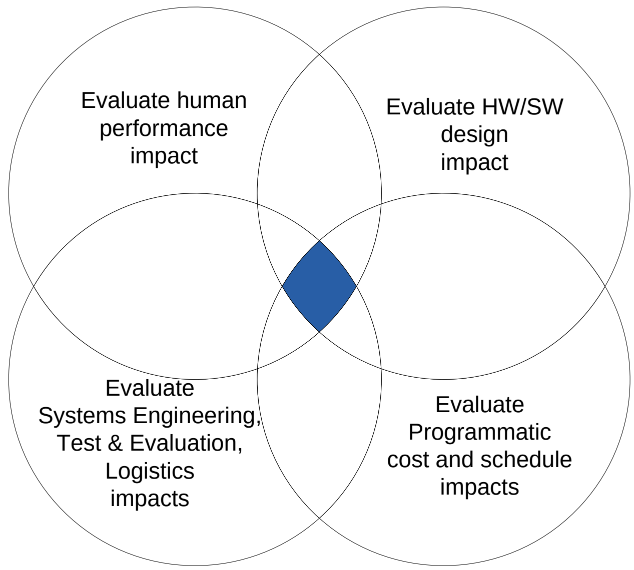

Figure 1: HSI Tradeoff Process

3.2 Decision Requirements Tables

The decision requirements tables further elaborate on the HSI practitioners' role in the HSI Tradeoff Process with specific decision activities. Seven decision activities were identified, with descriptions of (a) the cues that trigger each activity, (b) the factors that influence each activity, (c) the typical judgments made in the course of each activity, (d) the typical challenges faced in the course of each activity, (e) the strategies used to deal with the challenges. The complete decision requirements tables can be found in Appendix C. The seven decision activities are as follows:

- Workload/Manpower:
    1. Examine/ Investigate initial manpower estimate and the assumed workload for intended system design
    2. Create Program Risk for Manpower
    3. Perform analyses to confirm workload and manpower for the intended system design
- Hardware/Software (HW/SW) Changes:
    1. Evaluate initial system design for potential problems
    2. Follow-up with contractor after problem identification
    3. Government HFE(s) (without contractor) explore/generate design options to later present to contractor, Fleet, IPT, and/or program office (IPT and contractor may or may not simultaneously investigate other design options)
    4. IPT (including contractor) explores/generates design options to present to the program office [Iterative process]

Various cues such as Navy or DoD policy, emergent Fleet needs, design changes, test results, uncooperative contractors, or changes in program funding or resources are examples of occurrences that prompted a need to perform a tradeoff activity. Examples of factors that influenced the tradeoff activities include the availability of workload or task data, and time,

money and resources to perform analyses. Finally, the types of judgments that HSI practitioners make during the course of a tradeoff decision process are summarized as follows:

- Scope of Problem/Issue/Risk
- System Characteristics
- Alignment of Manpower Levels and System Design
- Analysis Process Used
- Data Quality and Reliability
- Adequacy of Analysis Results/System Redesign
- Program Office Impacts/Influences
- Contractor Performance

It is important to note that HSI practitioners are doing technical evaluations as well as process evaluations. Time is taken to judge data validity and accuracy, including reviews of analysis tools and methodologies used by others as well as themselves. Practitioners reportedly leveraged lessons learned from personal experience, advice from other practitioners and available information from past acquisition programs, industry and the research literature. These points are further highlighted in the content analysis results presented in the next section.

Finally, HSI practitioners face a variety of technical and programmatic challenges that impact the course of the tradeoff decision process for both Manpower/Workload and HW/SW changes. Table 2 summarizes the reported challenges, and what experts said they are doing to deal with them. It is very apparent that collaboration, coordination and discussion are key strategies for all of the challenges.

Table 2: HSI Tradeoff Challenges and Strategies

Challenges	Strategies
Working with a conceptual system design, a changing system design, and/or changing mission parameters	• Characterize the analysis results relative to what is known, understand the limitations of the analysis, document assumptions • Evaluate data collection and analysis methods used • Coordinate with SMEs for the most current information • Document system design as a risk (if appropriate) • Resolve through further analysis or testing • Modify the contract statement of work (if required)
Questionable data accuracy and reliability	• Evaluate data collection and analysis methods used • Resolve through further analysis or testing • Gather additional SME inputs • Government/contractor discussions or joint analysis efforts
Questionable requirements compliance or requirement applicability to the design	• Consult with other IPT members and SMEs • Resolve compliance issues with contractor through discussions (include management and contracting officer deemed necessary) • Revise the requirements (if appropriate)
Insufficient funding and/or staffing to perform analyses	• Petition for additional funding/resources • Leverage data from previous studies • Document as a risk (if appropriate)
Disagreements between HFEs and IPT members, program office, and other stakeholders	• Discussions, with supporting technical evidence • Rely on IPT leadership to manage team performance and HFE leadership to help resolve conflicts

3.3 Content Analysis Results

As described above, two main tradeoff categories were reported: Manpower/Workload and HW/SW changes. Figures 2 and 3 show the breakdown of these categories by the four macrocognition functions and processes (aka cognitive activities) identified by the content analysis. Because the same transcript data were used to perform the content analysis and create the decision tables, the text selections used in each analysis were aligned and counted. The percentages in the figures represent the number of overlaps, which reflects the levels of each cognitive activity used in each type of tradeoff. A summary of the mapping of the decision activities to the cognitive activities can be found in Appendix D.

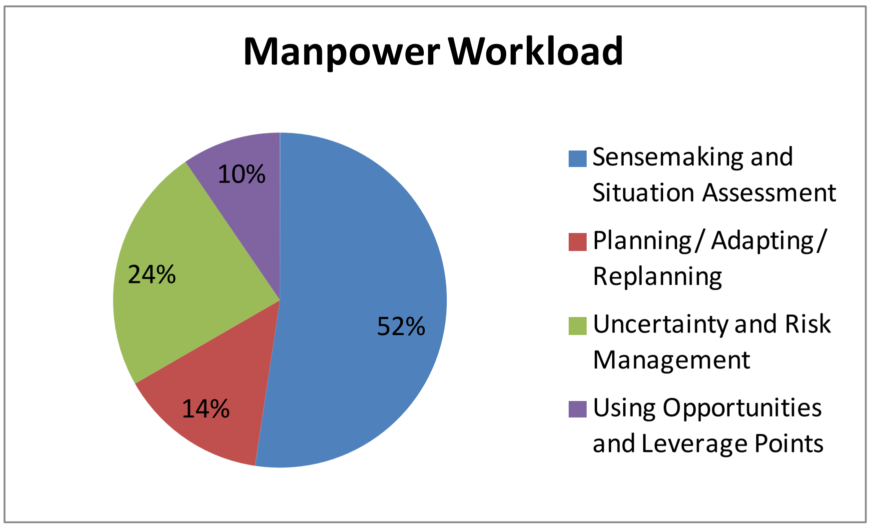

Figure 2: Manpower Workload Cognitive Activities

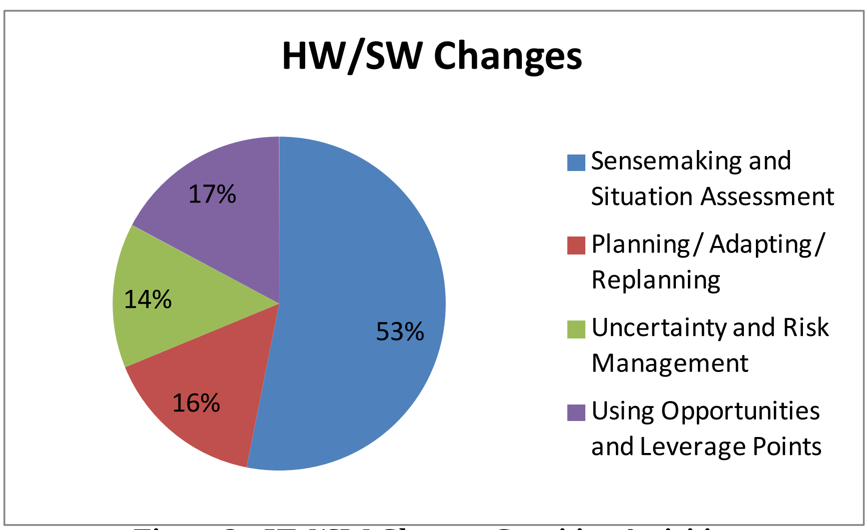

Figure 3: HW/SW Changes Cognitive Activities

Table 3 lists the frequency counts of segments for each cognitive activity from the content analysis. Because more than one code could be assigned to each text selection, and a

text selection could be assigned to more than one theme, the total frequency count is higher than the number of text segments.

Table 3: Frequency counts of segments for each code

Sensemaking and Situation Assessment	Planning/ Adapting/ Replanning	Uncertainty and risk management	Using opportunities and leverage points	TOTAL
231	46	34	29	340

The primary cognitive activity is sensemaking and situation assessment, where HSI practitioners perceive, evaluate, diagnose, anticipate, or create data and information in support of a tradeoff decision. Figure 4 depicts the frequency counts for the identified sensemaking themes. Note that CTR stands for "Contractor" and "Govt" means "Government.

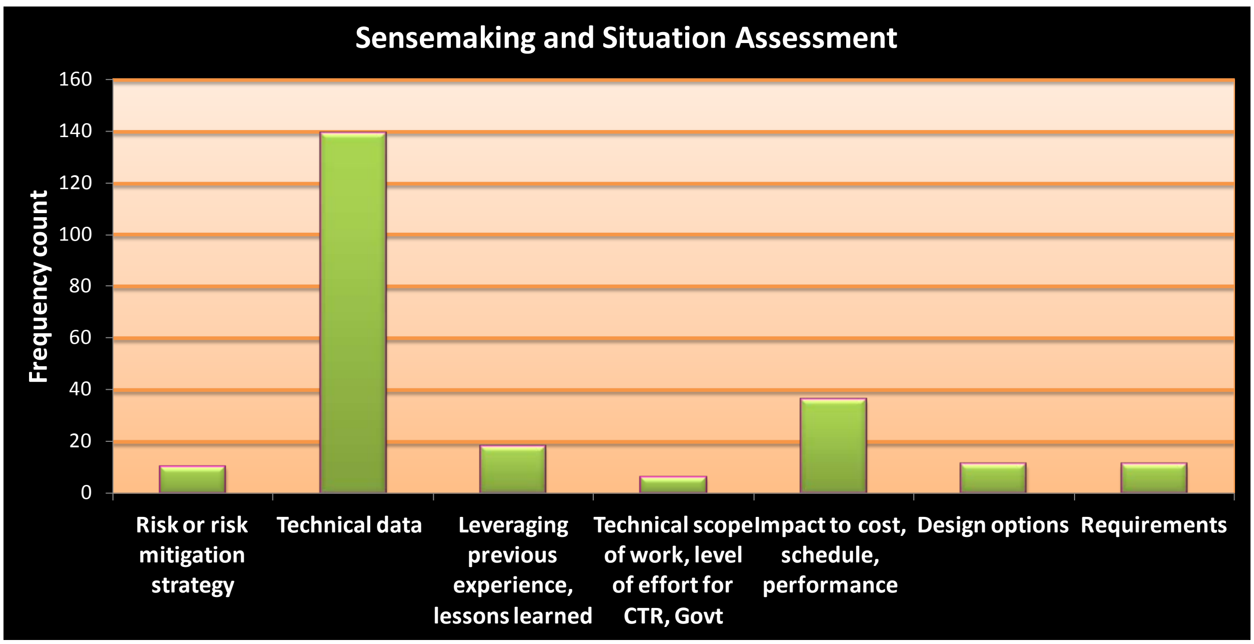

Figure 4: Sensemaking and Situation Assessment Themes and Frequency Counts

It comes as no surprise that evaluating technical data is the most significant (139 instances). Table 4 describes the technical data theme in further detail. The theme with the second highest frequency count in Figure 4 is assessing the impact of design features on cost, schedule and performance. For example, SMEs reported (a) evaluating the reliability of technology and the resulting impact on human performance effectiveness, (b) evaluating redesign efforts for requirements compliance, (c) evaluating and anticipating the impact of having limited time, money and people to perform analyses, and (d) evaluating sensitivities around adding manpower and the impact on total ownership costs and affordability. The majority of these impact assessments were done collaboratively with other IPT members.

Table 4: Subcategories for the Technical Data Theme

Technical Data Theme Subcategory	Examples
HFEs Primary (54 instances)	• Evaluated historical safety events, standards, instructions, requirements • Evaluated workload reduction through usability testing • Evaluated technology readiness levels and levels of automation (function allocation) • Perceived/Evaluated crew tasks and functions • Perceived/Evaluated environmental stressors to include in workload analyses • Perceived/Evaluated complaints about the user interface • Anticipated/Diagnosed potential user difficulty with the design • Evaluated/Mentally simulated interface use to create a storyboard
HFEs with Contractor, IPT, Program Office, Management, other Stakeholders (26 instances)	• HFEs and Program Office evaluated risk; collaborative discussions to finalize the wording of the risk • Perceived/Evaluated the interface design during the Human Machine Interface (HMI) working group meetings • Evaluated design during Air Crew Systems Advisory Panel (ASCAP) meetings • Perceived/Evaluated requirement; Discussed requirement with technical team (IPT level) • Perceived/Evaluated task analysis process during HFE group brainstorming session
Analysis results (28 instances)	• Perceived/Evaluated/Questioned manpower estimate created before the Systems Requirements Review (SRR) • Diagnosed that the baseline system used for the initial manpower estimate had very different attributes than current proposed system • Evaluated contractor equipment proposal and their justification • Evaluated data to validate what was being done during the analysis • Evaluated contractor response to potential design change • Anticipated need to instantiate/realize the assumptions made in the analysis to get desired workload
Data from Fleet, User Community, SMEs (20 instances)	• Perceived/Solicited design inputs through fleet user groups • Perceived/Evaluated responses from users; Diagnosed problem data • SMEs and Fleet representatives evaluated prototype • Fleet perceived/evaluated/raised concerns about the original design to the contractor
Data from literature review, prior studies, prior test events (11 instances)	• Perceived/Evaluated design using requirements and performance data from related research • Perceived/Obtained data for analysis from mission documents, tactical manuals • Diagnosed/Evaluated/Presented why the original design was insufficient using research and lessons learned • Perceived/Evaluated task lists and the Human Engineering Design Approach Document – Operator (HEDAD-O) for another aircraft to support interface design

Figure 5 shows that HSI practitioners are doing process planning as well as HW/SW evaluations; time is taken to evaluate the feasibility of courses of action during the tradeoff process. This includes deciding on the best path forward to conduct analyses and implement design changes. For example, SMEs reported planning to conduct future modeling and simulation analysis and test events to better understand the full impact of calculated workload. Project plans and schedules were also adapted because the HSI practitioners/IPT felt it was necessary to ask the contractor to verify the proposed changes before implementing them.

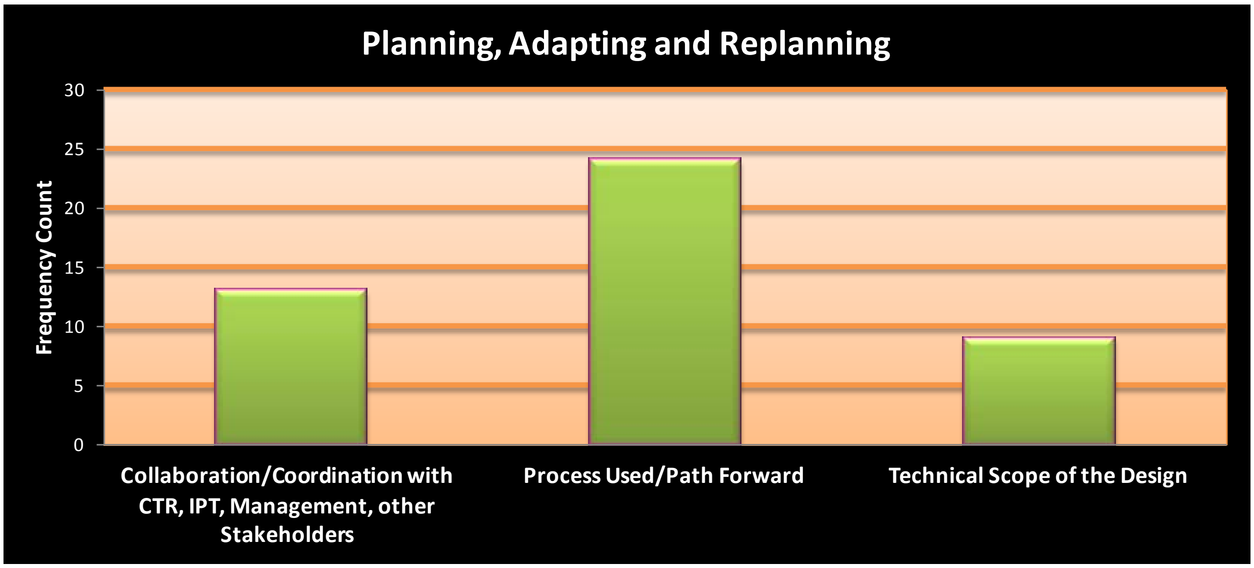

Figure 5: Planning, Adapting and Replanning Themes and Frequency Counts

The Uncertainty and Risk Management themes correspond with the judgments identified in the decision tables. As shown in Figure 6, HSI practitioners question the accuracy and reliability of data (e.g. time on task estimates, assumptions made), data analysis methods used (e.g. reproducible, valid, reliable), and data analysis results (e.g. number of proposed equipment, contractor provided cost estimates). Technology maturity, contractor reliability and the lack of adequate baseline comparison systems also contribute to the uncertainty. Judgments were made by both HSI practitioners and by the greater IPT on whether or not formal program risks needed to be created, and how best to proceed with the tradeoff in light of the uncertainty.

Figure 7 shows the themes for using opportunities and leverage points. HSI practitioners are actively coordinating with various program stakeholders to resolve conflicts and achieve a win-win situation for the tradeoff. In a HW/SW example, a prototyping event was conducted at the same time as a systems engineering technical review (SETR) event. Because of this timing, the SETR event would not be closed until the issues, major concerns and action items related to the prototyping event were resolved and closed. In a manpower/ workload example, task analyses were performed with members of the Training organization in order to support the development of training master task lists.

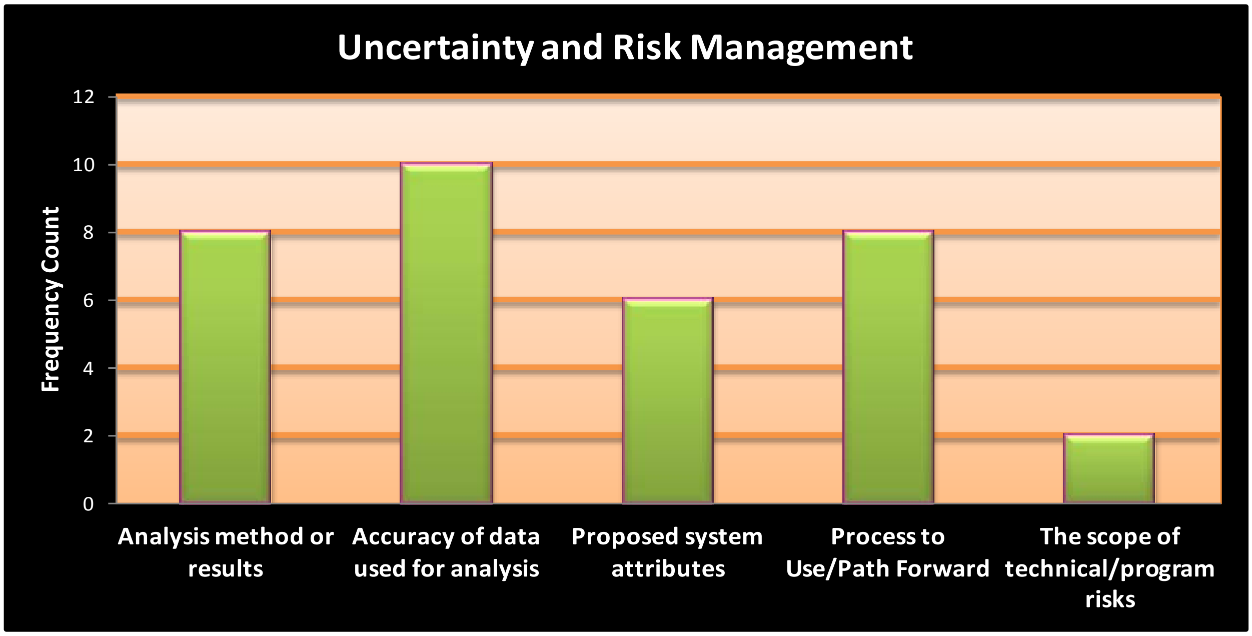

Figure 6: Uncertainty and Risk Management Themes and Frequency Counts

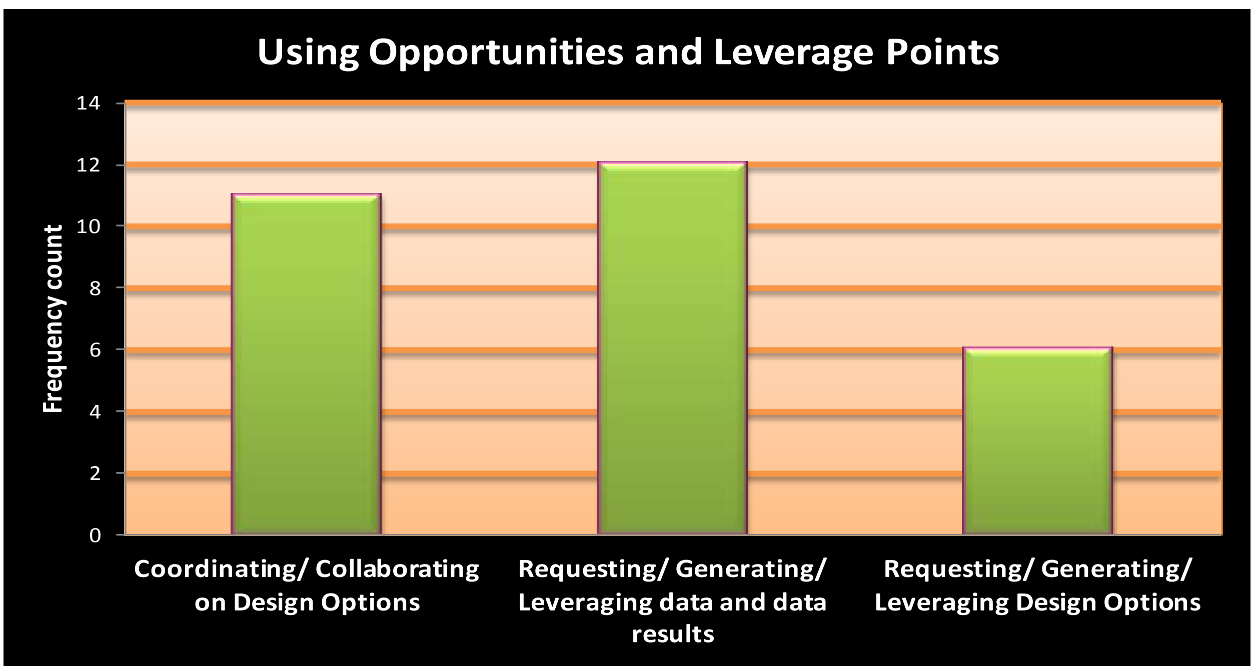

Figure 7: Using Opportunities and Leverage Points Themes and Frequency Counts

3.4 Relevant Knowledge and Experience

In summary, HSI practitioners are performing technical, process, risk and impact evaluations during tradeoff decisions. They are determining when and how to leverage previous work. They are planning and replanning analysis, testing and implementation processes. They take the time to evaluate current circumstances against previously experienced analogous situations. They also interface with IPT members, stakeholders in other organizations, and individuals they worked with in the past to gather and process information and data. But, what knowledge, skills and abilities are required to successfully execute these kinds of tasks?

3.4.1 Experience and What-Ifs

During the CDM interviews, SMEs were asked to describe the specific training or experience they felt was needed or helpful to them during the tradeoff incident they reported. They were also asked what they would have done differently, what would help another person make the same decision successfully, and what conditions, training, knowledge, information or tools might have helped made the decision process better. Table 5 lists the provided responses to these questions. These are not Knowledge, Skills and Abilities or Aptitudes (KSAs) as formally defined by the U.S. Office of Personnel Management (n.d.) or MIL-HDBK 29612 (2001). Further research would be required to develop a verified, validated and comprehensive list of HSI Tradeoff KSAs.

Table 5: Reported HSI Tradeoff Knowledge, Experience, Capabilities and Tasks

Knowledge of…	Experience in…	Additional Capabilities and Tasks
• Workload modeling tools and techniques • Where to find information • Technology readiness • Design	• Human factors, psychology, manpower, personnel, training • Human performance measurement, system design and training development • Workload analysis • Task analysis • Doing literature reviews • Understanding acquisition processes • Conducting research • Tradeoffs • Operational experience • The problem domain • Being assertive • Being patient • Managing teams	• Develop a valid baseline comparison • Derive requirements from user inputs • Use ACSAP process • Find Military Standards (MIL-STDs) • Investigate how manpower estimate was initially generated • Have a prototyping capability, ability to demonstrate high fidelity options • Develop arguments to present to program office; Have a way to determine cost, schedule and performance savings to present to the program manager • Gather more evidence on cost and performance; Investigate how the cost estimate was generated • Know how to determine when the contractor is right or wrong • Choose words carefully • Don’t take things personally • Understand how to approach problems • Know what to focus on • Be paired with someone experienced

3.4.2 Summarized Novice/Expert Differences

During the decision table interviews, SMEs were asked which actions described in the table clearly distinguished experts from novices, and what they thought novices might do in listed the activities. Appendix E contains a summary of the reported novice behaviors and training needs. There was considerable overlap with the skills described in the CDM interviews. However, the following are additional knowledge, experience and capabilities SMEs stated as required by novices to successfully work on HSI Tradeoff Decisions:

- Policy Familiarity
- Selecting the best analysis method for the situation
- Rescoping tasking (not just rescheduling tasking)
- Assessing the impact of data and data analysis on other functions
- (e.g. other HSI Domains, Systems Engineering, the contract, etc)
- Judging:
    - Accuracy of data, data results, or analysis progress
    - Adequacy/Accuracy of process/analysis outcomes
    - Adequacy/Accuracy of design options
- Predicting
- Process/Analysis outcomes
- Potential problems
- See the "big picture"
- Coordinate/Collaborate with stakeholders

4.0 CONCLUSIONS

This study represents a significant first step in trying to define how HSI tradeoff decisions are made. Due to the number of study participants, these results have limited generalizability, and therefore do not characterize all possible HSI tradeoff scenarios within Naval aviation.

However, it is clear from both the content analysis and the decision requirements tables that skills such as project management, team management, communication, negotiation, and risk assessment are required to complement the technical skills needed to perform HSI domain and cross-domain tradeoff analyses. It is also apparent from the research results that judgments of data quality and reliability are critical to the tradeoff process; time is also taken to evaluate the impact of questionable data on the design process. Considerable effort is also focused on presenting cost, schedule and performance decision rationales to program management, particularly for HW/SW tradeoffs. Successfully generating this argument requires time and resources to gather and evaluate information on contractor work plans, available funding, cost estimates (expenditures and savings) and quantitative and qualitative HW/SW and personnel performance impacts.

Therefore, it would be beneficial to develop and support these skills and capabilities within the HSI workforce. Further research is needed to identify specific HSI tradeoff KSAs, and determine which KSAs may require additional workforce training. For example, according to Cannon-Bowers and Bell (1996), naturalistic decision makers should receive training in areas such as metacognitive skills, reasoning, domain-specific problem solving, mental simulation, situation assessment and knowledge organization. The appropriate types of training would also

have to be evaluated. Means, Salas, Crandall and Jacobs (1993) recommend providing multiple trials in problem recognition and representation to develop skills for handling ill-structured problems, and training for monitoring, communicating, and providing/receiving feedback to handle multiple players involved in the decision making process. Finally, the feasibility of providing this additional training would have to be evaluated. Within any organization, it is a Management and Human Resources decision to either hire individuals with demonstrated performance in such skills, or to provide proficiency training for new and existing employees.

Additional research and development in HSI specific cost and risk assessment decision support tools may also benefit HSI practitioners. For example, a human performance assessment methodology or tool that quantifies and qualifies cost and risk at different points in the acquisition program using factors such as technology maturity, data validity, and perceived reliability of assumptions would allow HSI practitioners to present more reliable assessments to the Program Office. Collaborative partnerships with universities and other organizations currently working in this area would further support future research in HSI Tradeoffs.

REFERENCES

Bisantz, A.M., Roth, E., Brickman, B., Gosbee, L.L., Hettinger, L., & McKinney, J. (2003). Integrating cognitive analyses in a large-scale system design process. *International Journal of Human-Computer Studies*, *58*, 177–206.

Cannon-Bowers, J.A. & Bell, H.H. (1996). Training decision makers for complex environments: Implications of the naturalistic decision making perspective. In C.E. Zsambok & G.A. Klein (Eds). *Naturalistic decision making, pp 99-110*. New York, NY: Routledge.

Carletta, J., Isard, A., Isard, S., Kowtko, J.C., Doherty-Sneddon, G., & Anderson, A. (1997). The reliability of a dialogue structure coding scheme. *Computational Linguistics*, *23*, 13-32.

Chapanis, A. (1996). *Human Factors in Systems Engineering*. New York: John Wiley & Sons.

Cohen, M.S., Freeman, J.T., & Thompson, B.B. (1996). Training the Naturalistic Decision Maker. In C.E. Zsambok & G.A. Klein (Eds). *Naturalistic decision making, pp 257-268*. New York, NY: Routledge.

Coley, J.F. (2010). *Visualizing Subjective Decision Criteria For System Evaluation*. (Master's Thesis). Retrieved from http://web.mit.edu/aeroastro/labs/halab/publications.shtml

Crandall, B., Klein, G. & Hoffman, R.R. (2006). *Working Minds: A practitioner's guide to cognitive task analysis*. Cambridge, MA: MIT Press.

Cunio, P.M. & Cummings, M.L. (2009). *A Framework for an HSI Downselection Tool*, (HAL2009-03), MIT Humans and Automation Laboratory, Cambridge, MA. Retrieved from http://web.mit.edu/aeroastro/labs/halab/publications.shtml

Department of Defense Instruction 5000.02, Enclosure 8, Operation of the Defense Acquisition System, Human Systems Integration (2008). Retrieved from http://www.dtic.mil/whs/directives/

Department of Defense Handbook, MIL-HDBK-29612-4A, Glossary for Training. Retrieved from https://assist.daps.dla.mil/

Desmond, M.S. (2007). *Implementation of the Quantified Judgment Model to Examine the Impact of Human Factors on Marine Corps Distributed Operations* (Master's Thesis). Retrieved from http://calhoun.nps.edu/public/handle/10945/16

Fackler, J.C., Watts, C., Grome, A., Miller, T., Crandall, B. & Pronovost, P. (2009). Critical care physician cognitive task analysis: an exploratory study. Retrieved from http://ccforum.com/content/13/2/R33

Fleiss, J. L. (1971). Measuring nominal scale agreement among many raters. *Psychological Bulletin, 76* (5), 378–382.

Gwet, K. L. (2010). *Handbook of Inter-Rater Reliability, 2nd Edition*. Retrieved online at http://www.agreestat.com/book_excerpts.html

Higgins, L.A.& Mack, D. D. (2006). *A module for employing Human Systems Integration into the Rapid Equipping Force (REF)* (Master's Thesis). Retrieved from http://calhoun.nps.edu/public/handle/10945/16

Hoffman, R.R., Crandall, B. & Shadbolt, N. (1998). Use of the critical decision method to elicit expert knowledge: A case study in the methodology of cognitive task analysis. *Human Factors, 40*(2), 254-276.

Hoffman, R.R., Neville, K. & Fowlkes, J. (2009). Using cognitive task analysis to explore issues in the procurement of intelligent decision support systems. *Cognition, Technology & Work, 11*, 57–70.

Klein, G.A., Calderwood, R., & MacGregor, D. (1989). Critical Decision Method for Eliciting Knowledge. *IEEE Transactions on Systems, Man and Cybernetics, 19*(3), 462-472.

Klein, G. (1998). *Sources of power: How people make decisions*. Cambridge, MA: The MIT Press.

Krippendorff, K. (2004). *Content Analysis: An Introduction to its methodology*. Thousand Oaks, CA: Sage Publications, Inc.

Lazzaretti, P.C. (2008). *HSI in the USN Frigate Community – Operational readiness and safety as a function of manning levels* (Master's Thesis). Retrieved from http://calhoun.nps.edu/public/handle/10945/16

Liu, K.K. (2010). *Cost Estimation of Human Systems Integration*. (Master's Thesis). Retrieved from http://seari.mit.edu/documents/theses/SM_LIU.pdf

Macrae, C. (2009). Making risks visible: Identifying and interpreting threats to airline flight safety. *Journal of Occupational and Organizational Psychology, 82*, 273-293.

Malone, T.B., Pharmer, J., Lockett-Reynolds, J., & Muse-Duma, K. (2008). Integrated HSI. *Proceedings of the Human Factors and Ergonomics Society, 52*, 1954-1958.

Means, B., Salas, E., Crandall, B., & Jacobs, T.O. (1993). Training decision makers for the real world. In G.A. Klein, J.Orasanu, R. Calderwood, & C.E. Zsambok (Eds). *Decision Making in Action: Models and Methods, pp 306-326*. Norwood, NJ: Ablex Publishing Corporation.

Neale, H. & Nichols, S. (2001). Theme based content analysis: a flexible method for virtual environment evaluation. *International Journal of Human Computer Studies, 55*(2), 167-189.

Neuendorf, K.A. (2002). *The content analysis guidebook*. Thousand Oaks, CA: Sage Publications, Inc.

Office of Naval Research. (2009). Naval S&T Strategic Plan. Retrieved from http://www.onr.navy.mil/en/About-ONR/science-technology-strategic-plan.aspx

U.S. Office of Personnel Management. (n.d.). *General policies: Explanation of terms*. Retrieved from http://www.opm.gov/qualifications/policy/Terms.asp.

O'Hare, D., Wiggins, M., Williams, A., & Wong, W. (1998). Cognitive task analyses for decision centred design and training. *Ergonomics, 41*(11), 1698-1718.

Orasanu, J. & Connelly, T. (1993). The reinvention of decision making. In G.A. Klein, J.Orasanu, R. Calderwood, & C.E. Zsambok (Eds). *Decision Making in Action: Models and Methods, pp 3-20*. Norwood, NJ: Ablex Publishing Corporation.

Patterson, E.S., Woods, D.D., Cook, R.I., & Render, M.L. (2007). Collaborative cross-checking to enhance resilience. *Cognition, Technology & Work, 9,* 155–162.

Phillips, J., McDermott, P.L., Thordsen, M, McCloskey, M, & Klein, G. (1998). *Cognitive requirements for small unit leaders in military operations in urban terrain* (DTIC Research Report 355505). Retrieved from Defense Technical Information Center website: https://www.dtic.mil/DOAC/citation?document=ADA355505&collection=pub-tr&contentType=HTML&citationFormat=1f&index=7

Phillips, J., McCloskey, M.J., McDermott, P.L., Wiggins, S.L., Battaglia, D.A., Thordsen, M.L, & Klein, G. (2001). Decision-Centered MOUT Training for Small Unit Leaders. (DTIC Research Report 394066). Retrieved from Defense Technical Information Center website: https://www.dtic.mil/DOAC/citation?document=ADA394066&collection=pub-tr&contentType=HTML&citationFormat=1f&index=4

Stanton, N.A., Stewart, R., Harris, D., Houghton, R. J., Baber, C., McMaster, R., Salmon, P., Hoyle, G., Walker, G., Young, M. S., Linsell, M., Dymott, R. & Green, D. (2006). Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. *Ergonomics*, *49* (12–13), 1288–1311.

Taylor, H. (2007). An Examination of Decision-Making in IT Projects from Rational and Naturalistic Perspectives. *Proceedings of the Twenty Eighth International Conference on Information Systems*, 1-17. Retrieved from http://aisel.aisnet.org/icis2007/30/

Simpson, M. (2006). *Toward an improved method of HSI evaluation in Defense acquisition* (Master's Thesis). Retrieved from http://calhoun.nps.edu/public/handle/10945/16

Wong, B. L. W. (2004). Critical Decision Method Data Analysis. In *The Handbook of Task Analysis for Human-Computer Interaction*, edited by D. Diaper and N. Stanton, pp. 327–346. Mahwah, NJ: Lawrence Erlbaum & Associates.

Zannier, C., Chiasson, M., & Maurer, F. (2007). A model of design decision making based on empirical results of interviews with software designers. *Information and Software Technology, 49*, 637–653.

APPENDIX A – Critical Decision Method and Decision Table Interview Questions

Demographic Questionnaire

Participant # _________

1. What is your educational background (e.g. B.S. American Studies, M.S. Industrial Engineering)?
2. How many years of DoD acquisition experience do you have?
3. List the different roles/positions you had during your years of acquisition service
4. How many years of specifically Naval Aviation work experience do you have?
5. How many years of specifically HSI experience do you have?

Interview and Critical Decision Method Probe questions

1. Incident Selection: The interviewer will ask the SME to select a HSI tradeoff that occurred within the last 5 years. The SME will be asked to answer the following questions:

    a. What was the Naval Aviation acquisition and what type of program was it (e.g. ACAT I, II, etc)?
    b. Did the tradeoff decision concern a component, subsystem, system, family of systems, system of systems, process or procedure?
    c. Which HSI domains were involved in the tradeoff decision?
    d. What was your role on the program when the decision occurred?
    e. How many years of experience did you have on that specific acquisition program when the decision occurred? How many years of total acquisition experience did you have when the decision occurred?

2. Incident Recall: The SME will be asked to describe the events that occurred before, during and immediately after the decision was made.

3. Clarification: The interviewer will be asked to retell the incident, focusing on the timeline, critical incidents and decision points. The SME will have the opportunity to clarify, correct or add more information.

4. Probe Questions: The interviewer will ask the probe questions, allowing the SME to further elaborate on the critical incidents, decision points and other factors that affected the decision making process. The probe questions were adapted from Hoffman, et al (1998), O'Hare et al, (1998) and Taylor (2007). Questions for clarification (e.g. How? Why?) will be asked when appropriate.

5. What if queries: The interviewer will ask the hypothetical questions, allowing the SME to speculate on how their decision making process could have been better or how the decision may have been different if key features of the situation were different.

Probe Type	Probe Content
Personnel Interactions	Did you have the final say in the decision? If no, which other personnel were the key players in the decision?
Planning	Had you or anyone else anticipated the possibility of this tradeoff earlier in the acquisition timeline? Were any contingency plans made? What happened to those plans?
Situation cues	What factors facilitated the need for the tradeoff? How did you know for sure that a tradeoff was necessary?
Goals	What were the specific goals and objectives when the decision making process began?
Analogs	Did this situation remind of any previous work experience? If yes, how did it impact your approach for this decision?
Information	How did you determine what information was required to make the decision? How was the information obtained?
Influence of uncertainty	At any stage, were you uncertain about either the reliability or the relevance of information that you had available? If yes, what happened?
Options	What limitations did you face regarding possible alternatives? What other courses of action were considered or were available?
Decision making	Were there any factors that impacted the decision making process? How much time pressure was involved in making this decision? How long did it take to actually make this decision?
Errors	Were possible mistakes in the decision process anticipated? How were they avoided? Did any mistakes occur? If yes, how were they corrected?
Basis of choice	How was the final option selected and other options rejected? What rule was being followed? What was your specific contribution?
Mental modeling	Did you imagine the possible consequences of the final option? Did you imagine the events that would unfold as a result?
Results of actions	Did the tradeoff work as expected? If not, what might have caused it not to work?
Experience	What specific training or experience was necessary or helpful in making this decision? Do you think that you could develop a rule, based on this experience, which could assist another person to make the same decision successfully? Do you think that anyone else would be able to use this rule successfully? Why? Why not?
Hypotheticals	With hind-sight, what would you have done differently? What conditions, training, knowledge, information or tools might have helped made the decision process better? What would have happened if the tradeoff hadn't worked? What would you have done?

Decision Table Verification and Validation Interview Questions

After the informed consent forms have been signed, the interviewer will explain to the SME the background of the ILIR and the current progress to date. The interviewer will then review the decision tables with SME.

For each activity listed in the table, the interviewer and SME will discuss the cues, judgments, challenges and strategies used to address the challenges that were discovered using the five case studies. Discussion will center around the following questions:

- Do you have any comments about the cues, judgments, challenges and strategies listed in the table? Is there anything you think should be added or removed? Please provide reasons why.

- Are there any other activities that you think should be added to this table? Why?

- What factors do you think impact the various activities listed in the table? Why?

- Which actions described in this table do you think are the most challenging? Why?

- Which actions described in this table do you think clearly distinguish experts from novices? Why?

- Considering the list of experience used and useful tools/techniques/skills, is there anything you would add to this list? Why?

APPENDIX B – Summarized Responses to the CDM Interview Probe Questions

Question	Workload Analyses	HW/SW/Process Changes
Summary of Tradeoff Decision	These were not tradeoff decisions per se. They were verifications that the planned crew size was sufficient to perform the mission and that the workload was reasonable considering the mission and system design.	HW/SW/Process/Procedure design changes for requirements/standards compliance, workload mitigation, improved usability, and/or to minimize impact to training design
Interact 1: Did you have the final say in the decision?	Yes/ Will have a final say for analyses not complete at the time of the study	Yes/ Will have a final say for analyses not complete at the time of the study
Interact 1a: If no, which other personnel were the key players in the decision?	Even though participants had or will have a final say, other personnel were/will always part of the decision: Human Factors Engineers and their management (Gov't and Industry) Fleet Representatives Subject matter experts (Gov't and Industry) IPT members from other NAVAIR departments, NAVY program offices and Contractor/Subcontractor organizations	Even though participants had or will have a final say, other personnel were always part of the decision: Human Factors Engineers and their management (Gov't and Industry) Fleet Representatives Subject matter experts (Gov't and Industry) IPT members from other NAVAIR departments, NAVY program offices and Contractor/Subcontractor organizations
Plan 2: Had you or anyone else anticipated the possibility of this tradeoff earlier in the acquisition timeline?	Evidence existed but formal analysis was not requested until a program office risk was written	No Evidence that Fleet representatives had suspicions.
Plan 3: Were any contingency plans made?	No	No
Plan 3a: What happened to those plans?	N/A	N/A

Question	Workload Analyses	HW/SW/Process Changes
Cue 1: What factors facilitated the need for the tradeoff? [What was seen or heard?]	Comparison made to similar systems Information from the research literature Actual research and test results Fleet inputs Formal risk identified and documented Judgments from lessons learned and experience	Current design reviewed
Cue 2: How did you know for sure that a tradeoff was necessary?	The program could not move forward without verified and validated manpower and workload estimates	Design review highlighted non compliance with requirements and standards Personal and/or team judgment of potential consequences of current design
Goal 1: What were the specific goals and objectives when the decision making process began?	Quantify, verify, validate the workload and manpower estimates	Verify requirements Generate/Propose design options to meet requirements and standards, to improve usability, to manage user workload Solicit Fleet and SME feedback on design options
Analog 1: Did this situation remind of any previous work experience?	Yes	Yes

Question	Workload Analyses	HW/SW/Process Changes
Analog 1a: If yes, how did it impact your approach for this decision?	Lessons learned from previous experience impacted the level of detail and thoroughness of the analysis	Previous experience impact the data collection approach - made sure to review additional standards, requirements, technology readiness levels, previous research reports, literature review Lessons learned from previous experience placed an emphasis on getting Fleet and management support on the issue and design options prior to presentation to the program office
Info 1: How did you determine what information was required to make the decision?	Lessons learned from previous experience in workload and manpower analyses was used to determine what information was required	Consideration given on what would be needed to create a usable system Consideration given on what would be needed to create a comprehensive argument to the contractor and program office
Information needed	Use cases/Scenarios/Task Descriptions System characteristics (actual, projected) Who does what (human vs. system)? Best approximations/estimates of time on task under different environmental conditions	Requirements and standards Safety Data/Hazard Risk Index Task Descriptions System characteristics (actual, projected) Design characteristics of similar systems Previous test data and research results

Question	Workload Analyses	HW/SW/Process Changes
Info 1a: How was the information obtained?	Obtained/Requested from: • Mission description documents • User's Tactical Manuals • SMEs • Fleet Representatives • Contractors • Other IPT members	Obtained/Requested from: • Mission description documents • Human Engineering Design Approach Document - Operator (HEDAD-O) • User's Tactical Manuals • SMEs • Fleet Representatives • Contractors • Other IPT members
Analyses Performed	Baseline comparison analysis Timeline analysis Mission decomposition analysis/Crew task analysis Function allocation analysis User interface/Decision aid evaluations Created presentation to the program office	Reviewed current design Compared and contrasted different technologies Conducted a prototype/storyboard review Conducted a technology demonstration Generated design options Group consensus on best option Created white paper/presentation for the program office describing the pros and cons of the options and why one is best.
Uncertain1: At any stage, were you uncertain about either the reliability or the relevance of information that you had available?	Uncertain about contractor estimates for timeline analysis Uncertain about projected HW/SW capabilities	Uncertain about the contractor information on technology use Uncertain about contractor estimate of level of effort Uncertain about the existence of unique system requirements

Question	Workload Analyses	HW/SW/Process Changes
Uncertain1a: If yes, what happened?	Contractor questioned, but had to accept the estimates Had to accept at face value and use the data	Contractor questioned, but had to accept the estimates Consulted with other IPT members about requirements
Option 1: What limitations did you face regarding possible alternatives?	Additional cost for out of scope contractor tasking	Parts of the system could not be modified Some design options were infeasible due to impact on interfaces with other systems Some changes to operational process/procedure were infeasible due to downstream impacts
Option 2: What other courses of action were considered or were available?	Workload analysis had to be done - no option there Considered multiple crew configurations but no separate comparative analyses completed	Doing nothing was determined to be an infeasible option Redesigning the system/component and creating multiple redesign options was the only option
Decision 1: Were there any factors that impacted the decision making process?	Limited funding and resource availability (Gov't and contractor) Fleet input needed for verification Sensitivity around the cost of adding manpower to the program	Tension around impending contractual changes and the resulting cost implications in order to implement system redesign Anticipating contractor and/or program office pushback and preparing adequate counter arguments

Question	Workload Analyses	HW/SW/Process Changes
Decision 2: How much time pressure was involved in making this decision?	Time pressure to review contractor documentation in accordance with review schedule Need to complete analyses to support next milestone decision Need revised manpower estimate (based on workload analysis) since already post contract award	Time pressure to complete work within schedule Need to complete analysis before next technical review and/or test event No time pressure
Decision 3: How long did it take to actually make this decision?	Analysis not completed at time of study Analysis completed within one year	Analysis completed in six months Analysis completed in one month Analysis completed in three months
Error 1: Were possible mistakes in the decision process anticipated?	Anticipated that the desired data would not be obtained due to lack of funding and resource availability	No
Error 2: How were they avoided?	Not avoided	N/A
Error 3: Did any mistakes occur?	No	Not finding design problem sooner Not understanding the contractor's work breakdown structure (WBS) and development/delivery schedule
Error 3a: If yes, how were they corrected?	N/A	As soon as problem was discovered, redesign became a priority task Contractor schedule and WBS information became available indirectly through a request for action

Question	Workload Analyses	HW/SW/Process Changes
Choice 1: How was the final option selected and other options rejected?	N/A	Team consensus Cost evaluation
Choice 2: What rule was being followed?	N/A	Ensured design was requirement, standards, and safety compliant Ensured design aligned with Fleet feedback
Choice 3: What was your specific contribution?	Identified the consequences of not mitigating the workload risk Verified/Validated the analysis results and highlighted the implications of the analysis results for the program	Human factors engineering evaluations Key driver/facilitator for design option generation
Model 1: Did you imagine the possible consequences of the final option?	Identified the consequences of not mitigating the workload risk Used a database tool to characterize and model workload and perform sensitivity analyses	Considered design implications on user safety and user performance
Model 2: Did you imagine the events that would unfold as a result?	Used feedback from Fleet representatives and users of similar systems; also used information for relevant literature and lessons learned Performed sensitivity (what if) analyses	Envisioned how user would interact with each design option
Result 1: Did the tradeoff work as expected?	N/A Yes - Crew size was determined to be adequate for the system design with predicted capabilities	N/A Yes Yes
Result 1a: If not, what might have caused it not to work?	N/A	N/A

<table>
<tr><th>Question</th><th>Workload Analyses</th><th>HW/SW/Process Changes</th></tr>
<tr><td>Experience 1: What specific training or experience was necessary or helpful in making this decision?</td><td colspan="2">Experience in:
• Workload and task analysis
• Conducting research and literature reviews
• Human factors, psychology, manpower, personnel, training, Navy operations
• Conducting tradeoff analyses
• Understanding acquisition processes
• Being assertive
• Being patient

Knowledge of:
• Workload modeling tools and techniques
• Where to find information
• Technology readiness
• System design</td></tr>
<tr><td>Experience 2: Do you think that you could develop a rule, based on this experience, which could assist another person to make the same decision successfully?</td><td colspan="2">• Do task analysis
• Develop a valid baseline comparison
• Derive requirements from user inputs
• Use Air Crew Systems Advisory Panel (ACSAP) process
• Find Mil-Standards
• Develop arguments to present to program office
• Know how to determine when the contractor is right or wrong
• Choose words carefully
• Don’t take things personally</td></tr>
</table>

Question	Workload Analyses	HW/SW/Process Changes
Experience 3: Do you think that anyone else would be able to use this rule successfully? Experience 3a: Why? Why not?	Need experience in: • Managing teams • Human performance measurement • System design and training development Need relevant education, experience and exposure Need to: • Understand how to approach problems • Know what to focus on • Be paired with someone experienced	
What If 1: With hind-sight, what would you have done differently?	Gathered more evidence on cost and performance of other design options Investigated cost data and how the cost estimate for design options were generated Found the problem sooner, particularly when examining analogous situation Investigated how manpower estimate was initially generated Done more homework on requirements and contractor work plans and funding levels	
What If 2: What conditions, training, knowledge, information or tools might have helped made the decision process better?	Having a way to determine cost, schedule and performance savings to present to the program manager Having training in human factors Having experience in the problem domain Having funding and resources Having a prototyping capability; Demonstrating high fidelity options; Doing a prototype assessment	

Question	Workload Analyses	HW/SW/Process Changes
What If 3: What would have happened if the tradeoff hadn't worked? **What If 3a: What would you have done?**	Program Risk would have remained until another mitigation found Workload risk would have been created System may have not passed the next technical review or failed developmental testing	

APPENDIX C – Decision Requirements Tables

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
Workload/Manpower: **Examine/ Investigate initial manpower estimate and the assumed workload for the intended system design**	A policy or statue requiring a manpower analysis A program manpower Key Performance Parameter (KPP) (either exists or not) A program level manpower risk (either exists or not) The Analysis of Alternatives (AoA) results favor a system design that requires a reduced crew size. Stakeholders (NAVAIR manpower, NAVMAC, HFEs, SMEs, Fleet Reps, etc) judge the manpower estimate to be invalid.	A lack of supporting analysis for the existing manpower requirement or the manpower estimate The AoA and Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities (DOTMLPF) results The characteristics of: • the baseline comparison system (has very different attributes than the proposed system) • the billets under consideration • Big Navy personnel requirements • operational tempo and mission needs Using lessons learned	Judge the validity of the process and methodology used to do the manpower analysis (not a critique of the end result at this point). Suspicion in the process used would make the manpower number or end result questionable. Judge the validity of the manpower/workload assumptions made Judge the adequacy of a demonstrated understanding of the concept of operations (CONOPS) and the intended use of the system within that context Judge how the platform/system would operate within the battle space. Judge the level of automation and	• There is little confidence in the resource information and data used in the analysis. o Strategy: Invoke a different analysis to pull in credible information and artifacts. • The concept of operations is not very detailed and/or largely fluid at any point in the analysis. o Strategy: Characterize the analysis results relative to what is known, and understand the limitations of the analysis and the estimate itself. Include a range of possible outcomes. • Stakeholders do not see the value in evaluating or changing the manpower levels and do not support conducting the analysis. o Strategy: Estimate the impact of performing a manpower analysis. Explain how a change would benefit the crew and the program. Use a lot of face time and tailor the conversation depending on the stakeholder (e.g. use a scientific approach, personal approach, etc).

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
	A recognized need to verify assumptions on the number of crew and crew capabilities New prototype test results Changes in: • program funding (plus-up or plus-down) • the system's design • mission parameters	from previous experience to guide the analysis	technology immaturity to determine whether or not the manpower will be able to support the task and missions.	• There is insufficient funding to do the analysis. o Strategy: Document it as a risk; petition for additional funding. • The baseline system is very different than the new proposed design, which doesn't exist. o Strategy: Conduct multiple focus groups with the Fleet/SMEs. Perform detailed task analyses, to understand the task, the people and the mission. Coordinate with HW/SW engineers to understand the unknowns and deltas.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
Workload/Manpower: **Create Program Risk for Manpower**	HFE(s) and other IPT members raise concerns about workload and manpower A systems engineering technical review board identifies a need for a manpower risk and mitigation strategy A lack of supporting analysis for the existing manpower requirement or the manpower estimate The results of a manpower model, simulation model, concept of operations exercise or other usability test indicates the potential for a risk The program does not have enough resources to adequately assess the	The existence of a strong manpower requirement or KPP The availability of workload or task data Leveraging data from previous workload studies Using lessons learned from previous experience to gauge the likelihood, severity and consequences of the risk The need to formally track manpower concerns The need to generate different manpower and system design strategies by the next milestone review if the manpower assumptions cannot be verified.	Judge whether the program office will approve the use of resources to do a confirmation study. Judge whether or not the design supports the current manpower. Judge the likelihood of a problem if the workload is determined to be greater than number of crew allocated Judge the impact of the manpower levels on the design itself. Judge the impact of a manpower increase or decrease on warfighters' quality of life Judge the potential cost of additional manpower and impact to the	• Neither the Government nor the contractor is funded to perform the desired level of workload or manpower studies. o Strategy: Contractors perform planned analyses within contract scope, leveraging previous studies and literature reviews. • Stakeholders disagree on the characterization of the risk: ➢ Not enough equipment to accommodate the missions versus not enough people to do the mission ➢ Whether or not an issue is actually a risk ➢ Who should own the risk ➢ Workload focus: utilization versus cognitive workload o Strategy: Conduct multiple discussions until group consensus is achieved. Involve HFE management as needed to facilitate/mediate the discussions. • It unclear how best to demonstrate that adding/removing people or changing the design will mitigate the manpower risk. o Strategy: Define the options, work through them via analysis, then do a real live test of some sort, using a score sheet to evaluate options.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
	task environment	The need to tradeoff interface design and mission capabilities (can't have or do everything within the task environment)	program Judge what mitigation steps are available and whether or not they can get approved by the program office.	• The risk is not accepted by the program office because it could not be proven that the proposed upgrades would support the available manpower. o Strategy: Involve HFE leadership in discussions with Program Office to facilitate/mediate discussions.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
Workload/ Manpower: **Perform analyses to confirm workload and manpower for the intended system design**	A program level manpower risk A requirement mandating a manpower analysis The Analysis of Alternatives (AoA) results favor a system design that requires a reduced crew size. A recognized need to validate the current manpower estimate or revise the manpower estimate A recognized need to verify assumptions on the number of crew and crew capabilities Using intuition and lessons learned from previous experience, a determination is made that further	Available time, money and resources to do the analysis Available software and analysis methods to do the analysis Whether or not the analysis results will impact: • the work of other IPT members and/or program stakeholders • rate retention for relevant billets The need to communicate the impacts of the manpower risk to program office and other Navy organizations The need to generate different manpower and system design strategies by the next milestone review if the manpower	Judge the quality and reliability of: • the method to determine which tasks to focus on for the analysis, • the scope of the analysis, • the data used for the analysis, • the data sources (include personnel backgrounds and experience), • the assumptions, predictions and approximations made about the system's capabilities, • the time on task and workload assessments Judge the quality of the workload and manpower analyses considering: • confidence in the contractor, • what can be	• HFEs and Non-HFE stakeholders do not agree on the specific tasks to analyze (i.e. can't include every task) o Strategy: Discuss, scope down, prioritize, and gain consensus. • The task model needs to be accurate and validated. o Strategy: Use reliable and established modeling techniques. For the task analysis, rely on SMEs for task flow and timings. Validate against human in the loop testing. • The contractor puts off doing work that's in the contract. o Strategy: Fight for them to do it, move the deliverable up in the schedule, or work with available information (do without the analysis until it is completed) • The contractor's timeline analysis lacks rigor (i.e. it is quick and dirty). o Strategy: Government and contractor discuss the validity of data sources and analyses used. Find leverage within standards and requirements to determine whether or not the workload estimates are accurate or if contractual obligations have been met. If subject to cost and schedule constraints, accept the data as is. • SMEs and users provide questionable input for the workload analysis o Strategy: Interview multiple SMEs/Fleet reps. Remove inconsistent data as outliers or

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
	analysis should be done. The contract requires the completion of workload studies to determine the actual number of equipment needed.	assumptions cannot be verified. Using lessons learned from previous experience to guide the analysis and the level of detail in the analysis.	accomplished with available time, money, and resources • planned modeling and simulation efforts and the next major test event will validate the workload and manpower	verify/validate with other users • The analysis reveals a need to modify the design in a way that is beyond the original contract scope. o Strategy: Make a formal request to the program to add scope to the contractor's statement of work (contract modification) • There is a need for a revised manpower estimate, even though the workload analysis is not yet completed. o Strategy: Perform a parallel effort to understand the potential negative impacts of the type of work, workload and work circumstances; revise the estimate.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
HW/SW Changes: **Evaluate initial system design for potential problems**	A requirement to review the design as part of the normal systems engineering process. The phase of the acquisition program The contractor provides either one design or proposes multiple design options and strategies. A capability need from the user community doesn't exist in the design or the requirements, and requires a change to the current HW/SW configuration. A need to review proposed designs as part of a source selection process.	Contractor/sub contractor performance and experience with system The contractor's understanding of the design requests, the user community and the users' tasks The availability of Fleet Reps/SMEs to review the design The level of Government interest and involvement in the design process. The visibility of the system by the program office or key stakeholders. The cost to evaluate the system or the make a HW/SW or schedule change A need to control requirements creep.	Judge which approach should be used to evaluate the design (focus group, prototype testing, simulation, etc) Judge the adequacy of a paper analysis to assess the design versus using an actual prototype Judge which stakeholders need to participate in the design evaluation from the Government, contractor, Fleet, etc. Judge how the design compares to that of a similar system Judge the quality of the contractor's design, and their trustworthiness based on past performance	• There is not enough time or money to evaluate the design. o Strategy: Request more time/money • There is a lack of detail in the design and lots of assumptions o Strategy: Try to get more details; Ask for validation of assumptions • There is no design prototype available. o Strategy: Use more experienced people to evaluate the design. • More experienced SMEs who can actually mentally simulate the use of the proposed system are not available. o Strategy: HFEs extract what knowledge they can from less experienced SMEs/Fleet Reps, then guide them through a mental simulation. • Stakeholders outside of the program attempt to influence the design and the way it is evaluated. o Strategy: Involve people who have strong leadership and coordination skills and very strong technical backgrounds to screen unreasonable requests. Request program management support to minimize the inclusion of stakeholders who don't really need to participate.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
HW/SW Changes: **Follow-up with contractor after problem identification**	The identification of a potential performance issue or risk in the current design A need for design justification needed from the contractor The contractor requests input on proposed design options A capability need from the user community doesn't exist in the design or the requirements, and requires a change to the current HW/SW configuration. A change in the mission capabilities	HFEs cannot direct the contractor to make a design change Additional analysis is not in the current contract or within scope The level of program office support to question the contractor or ask the contractor to reevaluate/redesign the system. The willingness of the contractor to reevaluate/redesign the system. The potential cost of a contractual change A need to review the design in detail before the next test event or technical review A need to control requirements creep	Judge whether the issue/risk is a contractual issue, a human performance risk, or a requirement violation. Judge the criticality and significance of the problem Judge the adequacy of a proposed redesign to address the problem Judge confidence in the contractor	• Determine whether the design feature in question is within scope of the requirements. o Strategy: Consult with someone who knows the scope of the requirements and is able to make both a technical and contractual argument for the contractor to resolve the problem. If a resolution cannot be made one on one with the contractor, involve management and if necessary, the contracting officer. • Improper supporting analyses were done to generate the design. The contractor can't produce a substantive analysis that defends their design. This causes doubt that the design is compliant. o Strategy: Declare the design is noncompliant and determine whether or not it fails to meet contractual obligations. Propose (a) that an analysis be performed to substantiate the design, (b) rework the design, or (c) some other contractual actions for mitigation. Create a program risk if deemed necessary. • The contractor is uncooperative and thinks the design does not need to be changed. They think they are right and the Government is wrong, pushes back on generating alternatives. o Strategy: Request further substantiation of their position. Find the right requirements to map to the problem found. Seek advice from other HFEs. Contact the program office

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties Strategies/Mitigations
				and/or the contractor's management. Do a comparison of the system's performance as designed to the required/needed performance criteria Generate design alternatives using Government resources only. • HFEs identify an issue, a desire to resolve it, and a need for time, money and resources. The program office does not agree that the issue is a problem worth resolving, and disapproves a request for additional time, money and resources for an analysis. o Strategy: Outline the concern from a scientific standpoint. Emphasize the consequences of the technical risk to program cost and schedule. Bring in supporting evidence from the Fleet, Safety and other stakeholders. Get management support. Backing down from the issue is also an option.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties?
HW/SW Changes: **Gov't HFE(s) (without contractor) explore/generate design options to later present to contractor, Fleet, IPT, and/or program office** **(IPT and contractor may or may not simultaneously investigate other design options)**	A design deficiency exists An immediate HW/SW need from the Fleet The contractor has difficulty translating requirements into design options (i.e. needs an example from the Government) Open action items from a previous technical review that are dependent on system redesign Lack of funding for the current contractor to do additional analyses An uncooperative response from contractor to change the existing design	A need to meet system and manpower requirements A change in requirements A desire to redesign the system to have commonality with similar systems Familiarity with technology alternatives, including state of the art Fleet interest in specific technologies Using lessons learned from previous experience to redesign the system	Judge the necessity of changing the design Judge the adequacy of reusing HW/SW to change the design Judge whether the proposed design option is viable from a human performance standpoint Judge if the redesign options are more cost effective than the original Judge whether the proposed design fits into the acquisition scheme, if the work was already part of the contract, and/or the estimated cost for testing and integration is feasible. Judge the reliability of contractor cost estimates	• There are limited Government resources to change the design. o Strategy: Either add more resources or accept the risk of current system performance and move forward. If the system can't be redesigned, wait and see if the concern materializes in actual test. • The program office objects to the cost of changing the design (e.g. contract modification, revise the drawings, perform additional testing, etc.). o Strategy: HFEs prepare a human performance and/or safety focused response to justify the cost of proposed design(s) and emphasize why it is worth the additional cost.

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties?
HW/SW Changes: **IPT (including contractor) explores/generates design options to present to the program office** **[Iterative process]**	The program office did not approve the design options proposed by the Government HFEs (see previous decision activity) No current design exists A design deficiency exists Open action items from a previous technical review that are dependent on system redesign The contractor has difficulty translating requirements into design options (i.e. needs an example from the Government) Program redirection	The complexity of the design change (modify HW/SW and operational/maintenance procedure) Certain elements of the system cannot be modified The availability of materials, HW/SW to implement the proposed design changes Level of cooperation/collaboration between IPT members Using lessons learned from previous experience to redesign the system Availability of funds to do the redesign work Cost to implement the design change	Judge the risk of having a non-compliant design Judge which IPT members and/or stakeholders need to be involved in the redesign effort Judge whether the design alternatives/options fit within existing requirements or there is a need to changes the requirements. Judge the impact of redesign implementation on program cost and schedule Judge the reliability of the contractor cost estimate for system integration after redesign	• Some IPT members are uncooperative, have conflicting personalities o Strategy: Rely on good IPT leadership to manage team performance, like a team coach. • The system's architecture restricts potential design changes (e.g. space limitations, computer processing capacity, etc) o Strategy: Consider workarounds and additional design options • The logic behind a unique system requirement is questionable. o Strategy: Consult with other IPT members on the origin and the logic behind the requirement. • The system redesign is being held accountable to the original system's requirements, some of which may no longer apply. o Strategy: Revise the requirements • Some IPT members, including the contractor, try to work around the Government HFEs by getting other people to do the work and/or going directly to the users. o Strategy: Talk to the IPT members

Activities	Cues What triggers this activity?	Factors What influences this activity?	Judgments	Challenges/ Difficulties?
				and try to reestablish more effective relationships. Talk to the program office and the people that they were going to and make them aware of the coordination/collaboration problem. Inform HFE management and let them decide if they want to pursue the violation or not.

APPENDIX D – Cognitive Activities Mapped to Decision Activities

	Examine/ Investigate initial manpower estimate and the assumed workload for intended system design	Create Program Risk for Manpower (if deemed necessary)	Confirm workload and manpower for new system design	Evaluate initial system design for potential problems	Follow-up with contractor after problem identification	Gov't HFE(s) (without contractor) explore/generate design options to later present to contractor, Fleet, IPT, and/or program office	Entire IPT with contractor(s) explore/generate design options to present to the program office [Iterative process]
Sensemaking and Situation Assessment							
Risk or risk mitigation strategy	X	X	X	X	X		
Impact to Cost, Schedule, or Performance			X	X		X	X
HFEs with Contractor, IPT, Program Office, Management	X	X	X	X	X	X	X
HFEs with Fleet, User Community, SMEs	X		X	X	X	X	X
Technical data (Primarily HFE(s))	X		X	X	X	X	X
Analysis results	X	X	X	X	X	X	
Technical scope of work/ level of effort for Contractor or Government		X	X		X		X

	Examine/ Investigate initial manpower estimate and the assumed workload for intended system design	Create Program Risk for Manpower (if deemed necessary)	Confirm workload and manpower for new system design	Evaluate initial system design for potential problems	Follow-up with contractor after problem identification	Gov't HFE(s) (without contractor) explore/generate design options to later present to contractor, Fleet, IPT, and/or program office	Entire IPT with contractor(s) explore/generate design options to present to the program office [Iterative process]
Design options	X		X			X	X
Requirements				X		X	X
Leveraging previous experience and lessons learned	X		X	X	X	X	X
Literature review, prior studies, prior test events	X		X	X		X	X
Planning/ Adapting/ Replanning							
For collaboration/ coordination with contractor, IPT members, Management, other Stakeholders		X		X	X	X	X
Process Used/Path Forward	X		X	X	X	X	X
Technical Scope of the Design	X	X	X	X			X
Uncertainty and Risk Management							
Validity of analysis method and/or analysis results	X		X			X	X
Accuracy and validity of	X	X	X			X	

	Examine/ Investigate initial manpower estimate and the assumed workload for intended system design	Create Program Risk for Manpower (if deemed necessary)	Confirm workload and manpower for new system design	Evaluate initial system design for potential problems	Follow-up with contractor after problem identification	Gov’t HFE(s) (without contractor) explore/generate design options to later present to contractor, Fleet, IPT, and/or program office	Entire IPT with contractor(s) explore/generate design options to present to the program office [Iterative process]
data used for analysis							
Proposed system attributes			X	X	X		X
Process to Use/ Path Forward			X	X	X		X
Scope of technical/ program risks	X	X	X				
Using Opportunities and Leverage Points							
Coordinating/ Collaborating on Design Options			X	X	X	X	X
Requesting/ Generating/ Leveraging data and data results	X	X	X	X	X	X	X
Requesting/ Generating/ Leveraging Design Options					X	X	X

APPENDIX E – Summarized Novice Behaviors and Training Needs

Novice Behaviors

- Lack experience and instincts (can't compare current work to past projects)
- Lack insight and good judgment.
- Follow procedure
- Tend to focus only on the task at hand. Don't see how the task fits in with the rest of the design process. Don't see design complexity.
- Focus on whether or not they are doing to task correctly
- Ask management for help and guidance on what to do
- Do what they are told
- Either try to tackle tasks without SME inputs or network/collaborate with experts to access their knowledge base.
- Focus primarily on design requirements compliance
- Lack confidence to stand their ground and assert their position
- Novices get passionate/emotional/unreasonable
- Don't know when to back down
- Don't know how to change their communication/presentation approach depending on audience
- Don't understand everyone doesn't think like them

Novice Needs

Knowledge of:

- Available analysis methodologies and toolsets
- Policy
- Operations and Missions
- Which stakeholders to involve in a design process

Skills in:

- Personal interaction
- Communication/Presentation
- Negotiation

How to:

- Identify and define risks, mitigations and risk exit criteria
- Assess the impact of a risk or design on cost, schedule or performance
- Select to best analysis method for the task (the one that will produce the most accurate data results)

- Assess the impact of HSI domain data and data analysis results on other functions (other HSI domains, HW/SW, cost, schedule, performance, contract scope, etc)
- Judge accuracy of data, data results, or analysis progress
- Judge the outcome of a process/analysis
- Judge the adequacy of design options
- Predict the outcome of a process/analysis
- Predict potential problems
- See the “big picture”
- See requirements issues
- See contractual issues related to technical issues
- Understand that contractors will push back because they are profit oriented
- Rescope tasking (not just reschedule tasking)
- Deviate from standards and still be compliant
- Judge/Estimate cost/schedule/performance impact
- Generate design options (more likely to ask contractor to generate them or seek guidance)
- Coordinate/Collaborate with stakeholders